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METHOD FOR EXTRACTING ZERNIKE/PSEUDO-ZERNIKE MOMENT

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TECHNICAL FIELD

The present invention relates to a method for extracting a Zernike/Pseudo-Zernike moment, and in particular, to a method for extracting a Zernike/Pseudo-Zernike moment by using the symmetry of a Zernike/Pseudo-Zernike moment basis function and computer readable recording medium on which a program implementing the same method is recorded.

BACKGROUND ART

In the conventional art, since a Zernike/Pseudo-Zernike moment includes an orthogonal basis function, it shows the characteristics of an image more efficiently than a geometric moment, Legendre moment, rotational moment and the like. On the contrary, a method for extracting a Zernike/Pseudo-Zernike moment has the following problem.

The method for extracting a Zernike/Pseudo-Zernike moment according to the conventional art includes the method for storing the result of repeated calculations on a look-up table and using the stored result in extracting a moment.

However, the above method used in extracting a moment requires much moment extraction time, and a large amount of memory utilization necessary for memory extraction is needed in order to store the look-up table.

On the other hand, another conventional method includes an

approximation method for approximating a Zernike/Pseudo-Zernike moment basis function in a square shape.

However, the above method has a problem that it is impossible to extract an accurate moment for an image, though a moment extraction speed can be increased.

DISCLOSURE OF THE INVENTION

Therefore, it is an object of the present invention to provide a method for extracting a Zernike/Pseudo-Zernike moment by using the symmetry of a Zernike/Pseudo-Zernike moment basis function for the purposes of rapid moment extraction and decrease in memory utilization and computer readable recording medium on which a program implementing the same method is recorded.

It is another object of the present invention to provided a method for extracting a Zernike/Pseudo-Zernike moment by using the symmetry of a Zernike/Pseudo-Zernike moment basis function.

In order to achieve the above-described objects of the present invention, there is provided a method for extracting a Zernike/Pseudo-Zernike moment for an input image according to the present invention, which includes the steps of: generating a Zernike/Pseudo-Zernike moment in a predetermined quadrant on a plane cartesian coordinates; obtaining a pixel value of the input image by projecting the input image onto the quadrant; and multiplying each pixel value of the input image by the moment basis function corresponding to the pixel position and then summing the results thereof.

In addition, there is provided a method for extracting a Zernike/Pseudo-Zernike moment for an input image according to the present invention, which includes the steps of: generating a Zernike/Pseudo-Zernike moment in a predetermined quadrant on a plane orthogonal coordinates; generating a Zernike/Pseudo-Zernike moment for all quadrants from the a Zernike/Pseudo-Zernike moment basis function on the quadrant by using the symmetry of a Zernike/Pseudo-Zernike moment; obtaining a pixel value of the input image; and multiplying each pixel value of the input image with the moment basis function corresponding to the pixel position and then summing the results thereof.

In addition, there is provided a computer readable recording medium on which a program implementing the same method is recorded, which includes the functions of: generating a Zernike/Pseudo-Zernike moment in a predetermined quadrant on a plane orthogonal coordinates in an image recognition system having a processor in order to extract a Zernike/Pseudo-Zernike moment; obtaining a pixel value of the input image by projecting the input image onto the quadrant; and multiplying each pixel value of the input image with the moment basis function corresponding to the pixel position and then summing the results thereof.

In addition, there is provided a computer readable recording medium on which a program implementing the same method is recorded, which includes the functions of: generating a Zernike/Pseudo-Zernike moment in a predetermined quadrant on a plane orthogonal coordinates in an image recognition system having a processor in order to extract a Zernike/Pseudo-Zernike

Zernike moment; generating a Zernike/Pseudo-Zernike moment for all quadrants from the a Zernike/Pseudo-Zernike moment basis function on the quadrant by using the symmetry of a Zernike/Pseudo-Zernike moment; obtaining a pixel value of the input image; and multiplying each pixel value of the input image with the moment basis function corresponding to the pixel position and then summing the results thereof.

Additional advantages, objects, and features of the invention will become more apparent from the description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a flow chart illustrating a method for extracting a Zernike/Pseudo-Zernike moment according to a first embodiment of the present invention;

Figure 2 is a flow chart illustrating a method for generating a Zernike/Pseudo-Zernike moment according to a second embodiment of the present invention;

Figure 3 is a view explaining symmetry with y=x, x-axis, y-axis, and origin;

Figures 4A and 4B are explanatory views of a Zernike moment basis function in the case that a repetition (m) is an even number;

Figures 5A and 5B are explanatory views of a Zernike moment basis function in the case that a repetition (m) is an odd number; and

Figures 6A and 6B are explanatory views of Zernike moment extraction from an input image.

MODES FOR CARRYING OUT THE PREFERRED EMBODIMENTS

The preferred embodiment of the present invention will now be described with reference to the accompanying drawings.

Figure 1 is a flow chart illustrating a method for extracting a Zernike/Pseudo-Zernike moment according to a first embodiment of the present invention.

As illustrated therein, the method for extracting a moment includes the steps of: obtaining a Zernike/Pseudo-Zernike moment basis function in a first quadrant in step 101; obtaining a pixel value an input image in step 102; and extracting a Zernike/Pseudo-Zernike moment by multiplying the moment basis function with the pixel value of the input image in step 103.

The step 101 of obtaining a Zernike/Pseudo-Zernike moment basis function in a quadrant will now be described.

First, the real radial polynomial of a Zernike moment and the real radial polynomial of a Pseudo-Zernike moment are obtained by using mathematical formulas 1 and 2 in step 104.

Sine the real radial polynomial of the Zernike/Pseudo-Zernike moment is orthogonal in a unit circle of $x^2 + y^2 = 1$, information redundancy is small.

The real radial polynomial Rnm'(ρ) of the Zernike moment is expressed by mathematical formula 1.

[Mathematical Formula 1]

$$\mathrm{Rnm}(\rho) = \sum_{s=0}^{(n=m)/2} (-1)^s \frac{(n-s)!}{s!\left(\frac{n+|m|}{2}-s\right)!\left(\frac{n-|m|}{2}-s\right)!} \mathrm{p}^{(n-2s)}$$

In addition, the real radial polynomial Rnm(ρ) of the Pseudo-Zernike moment is expressed by mathematical formula 2.

[Mathematical Formula 2]

$$\mathrm{Rnm}(\rho)=\sum_{s=0}^{n=m}(-1)^{s}\frac{(2n+1-s)!}{s!(n-m-s)!(n-m+1-s)!}\,\mathrm{p}^{(n-s)}$$

Here, n is an order, m is a repetition, and n and m must satisfy n - | m | = even number and | m | ≤n.

It is checked if the repetition(m) is an even number, i.e., m=2k in step 105. If the repetition(m) is an even number, a Zernike/Pseudo-Zernike basis function is obtained in step 107 by using y=x symmetry in step 106.

A Zernike/Pseudo-Zernike basis function with an order of n and a repetition of m is expressed by mathematical formula 3.

[Mathematical Formula 3]

$$\mathrm{Vnm}(x,y) = \mathrm{Rnm}(\rho)\ e^{jm\theta} = \mathrm{Rnm}(\rho)\cos m\Theta + j\,\mathrm{Rnm}(\rho)\sin m\Theta$$

$$= \text{real part} + j\ \text{imaginary part}$$

Here, with respect to Vnm(x,y), the polynomial Rnm(ρ) is multiplied by $e^{jm\theta}$, $e^{jm\theta}$ term is transformed into $(\cos m\Theta + j\ \sin m\Theta)$ by using Fourier Formula.

Here, the cost term and the sin term has a specific symmetry in a Cartesian coordinate system, Vnm(x,y) also has a specific symmetry(refer to Figures 4A through 5B).

The step of obtaining a pixel value of an input image in step 102 will now be explained below(refer to Figures 6A and 6B).

The pivot point of the input image is calculated to be adjusted to a unit circle size in step 108. Then, the pixel value of each point is obtained by projecting points existing in a fourth quadrant, second quadrant, and third quadrant by using x-axis symmetry, y-axis symmetry, and origin symmetry in step 109.

Here, the reason why the input image is adjusted to the size of a unit circle centering on the origin is that a Zernike/Pseudo-Zernike moment basis function is orthogonal in the unit circle.

The step of extracting a Zernike/Pseudo-Zernike moment by multiplying the moment basis function by a pixel value of an input image in step 103 will now be explained as follows.

The Zernike/Pseudo-Zernike moment is obtained by multiplying each moment basis function by the pixel value of the input image in step 110, and then summing the results thereof in step 111(refer to Figures 6A and 6B).

This will be mathematically expressed by Mathematical Formula 4, and the Zernike/Pseudo-Zernike moment is a complex number.

[Mathematical Formula 4]

$$\mathrm{Anm}=\frac{n+1}{k}\sum_{x}\sum_{y}f(x,y)Vnm^{*}(x,y)$$

Here, * represents a complex conjugate.

Generally, the Zernike/Pseudo-Zernike moment is considered the projection of the Zernike/Pseudo-Zernike basis function of the input image(refer to Figures 6A and 6B).

Figure 2 is a flow chart illustrating a method for generating a Zernike/Pseudo-Zernike moment according to a second embodiment of the

present invention.

As illustrated therein, the step of generating a Zernike/Pseudo-Zernike moment basis function in a first quadrant in steps 201 through 204 is the same as step 101 of Figure 1.

In addition, the Zernike/Pseudo-Zernike moment basis function in the remaining second, third, and fourth quadrants is obtained by applying x-axis symmetry, y-axis symmetry, and origin symmetry to the Zernike/Pseudo-Zernike moment basis function in the first quadrant as obtained in steps 201 through 204.

Moreover, unlike Figure 1, the pixel value of the input image is obtained for all the four quadrants without projecting the input image onto the first quadrant. Then, each pixel value is multiplied by the Zernike/Pseudo-Zernike moment basis function corresponding to the position of the pixel, and then the results thereof are added, thereby obtaining the Zernike/Pseudo-Zernike moment for the input image.

Figure 3 is a view explaining symmetry with y=x, x-axis, y-axis, and origin.

As illustrated therein, the symmetric points of a point P1(a,b) existing in the Cartesian coordinate system includes the symmetric point of x-axis, symmetric point of y-axis, symmetric point of the origin, and symmetric point of y=x.

The coordinates and phase angles of the symmetric points in the Cartesian coordinate system are shown in Table 1.

In obtaining Vnm(x,y) in the coordinates disposed in the symmetric

points, the symmetry of cosmθ and sinmθ is very important. Here, θ represents the angle between each point and a horizon line.

【Table 1】

Reference for symmetric point	coordinate	$\theta = \tan^{-1}(y/x)$
Reference point	P1 = (a, b)	θ
y-axis symmetry	P2 = (-a, b)	$\pi - \theta$
Origin symmetry	P3 = (-a,-b)	$\pi + \theta$
x-axis symmetry	P4 = (a,-b)	$-\theta$
Y=x symmetry	P1 ´ =(b, a)	$\pi/2-\theta$

Figures 4A and 4B are explanatory views of a Zernike moment basis function in the case that a repetition (m) is an even number.

As illustrated therein, the shape of the Zernike moment basis function in the case that the repetition(m) is an even number is shown.

With respect to each symmetric point, like Table 1, when the angle between each point and a horizon line, i.e.,θ is changed, the symmetry of cosmθ and sinm θ varies according to whether the repetition(m) is an even number or odd number. Here, the shape of the Zernike moment basis function in the case that the repetition(m) is an even number is explained.

Figure 4A illustrates the real part of the Zernike moment basis function, and Figure 4B illustrates the imaginary part of the Zernike moment basis function.

The Zernike moment basis function has a value between –1 and 1. The range of the value of the Zernike moment basis function is divided into 256 parts, in which a value close to –1 is denoted by black, while a value close to 1 is denoted by white.

As illustrated therein, the Zernike moment basis function has symmetry of a specific type for the x-axis, y-axis, and origin. Such symmetry is caused by the change in θ as shown in Table 1, which can be put in order as shown in Table 2.

【Table 2】

Reference for Symmetric Point	Coordinate	Real part	Imaginary Part
Reference Point	P1 = (a, b)	R	I
y-axis Symmetry	P2 = (-a, b)	R	-I
Origin symmetry	P3 = (-a,-b)	R	I
x-axis Symmetry	P4 = (a,-b)	R	-I

In the case that the repetition(m) is an even number, y=x also has symmetry. That is, the case of m=4k and the case of m=4k+2 has different types of symmetry.

In case of m=4k, the real part has the same value in symmetry with y=x, while the imaginary part has a value multiplied by –1.

In case of m=4k+2, both real part and imaginary part has a value multiplied by –1 in symmetry with y=x.

The above description will be also adapted to the Pseudo-Zernike moment basis function.

Figures 5A and 5B are explanatory views of a Zernike moment basis function in the case that a repetition (m) is an odd number.

As illustrated therein, the shape of the Zernike moment basis function in the case that the repetition(m) is an odd number is explained.

With respect to each symmetric point, like Table 1, when the angle

between each point and a horizon line, i.e.,θ is changed, the symmetry of cosmθ and sinm θ varies according to whether the repetition(m) is an even number or odd number. Here, the shape of the Zernike moment basis function in the case that the repetition(m) is an odd number is explained.

Figure 5A illustrates the real part of the Zernike moment basis function, and Figure 5B illustrates the imaginary part of the Zernike moment basis function.

The Zernike moment basis function has a value between –1 and 1. The range of the value of the Zernike moment basis function is divided into 256 parts, in which a value close to –1 is denoted by black, while a value close to 1 is denoted by white.

The symmetry in case of m=2k+1 is caused by the change in θ as shown in Table 1, which can be put in order as shown in Table 4.

【Table 3】

Reference for symmetric point	Coordinate	Real part	Imaginary part
Reference point	P1 = (a, b)	R	I
Y-axis symmetry	P2 = (-a, b)	-R	I
Origin symmetry	P3 = (-a,-b)	-R	-I
X-axis symmetry	P4 = (a,-b)	R	-I

The above description will be also adapted to the Pseudo-Zernike moment basis function.

Figures 6A and 6B are explanatory views of Zernike moment extraction from an input image.

As illustrated therein, Figure 6A illustrates the imaginary part of the Zernike moment basis function in case of n=m=3, and Figure 6B illustrates

an input image adjusted to the size as in Figure 6A.

The Zernike/Pseudo- Zernike moment is obtained by multiplying each pixel value of the input image by the Zernike/Pseudo- Zernike moment basis function corresponding to the position of the pixel and then summing the results thereof.

The method for obtaining the Zernike moment for the input image(Figure 6B) in the first quadrant only will be described, for example, in detail.

In the case that an order is 3(n=3) and a repetition is 3(m=3), the Zernike moment is obtained by multiplying each pixel value of the input image(Figure 6B) by the Zernike moment basis function corresponding to the position of the pixel, and summing the results thereof.

The pixel values of four points(denoted by black, round points on the drawings) having symmetry are represented as O, P, Q, and R. If the Zernike moment basis function corresponding to the position of pixel O is A, the Zernike moment basis functions corresponding to the positions of the remaining pixels P, Q, and R are A, -A, and –A, respectively, by x-axis symmetry, y-axis symmetry, and origin symmetry.

Here, with respect to the moment basis function and the pixel value of the input image, in case of binary image, black portions has a pixel value of 1, white portions has a pixel value of 0, or vice versa. On the other hand, in case of grayscale image, the pixel value is recognized a value between 0 and 255.

At this time, the Zernike moment(A33) for the input image is obtained

by [Mathematical Formula 5]

$$\text{Zernike moment(A33)} = O*(A) + P*(A) + Q*(-A) + R*(-A)$$

If Mathematical Formula 5 is changed to Mathematical Formula 6, the number of multiply operations is reduced from 4 to 1.

[Mathematical Formula 6]

$$\text{Zernike moment(A33)} = (O + P - Q - R) * A$$

In Mathematical Formula 6, the operation of (O + P - Q - R) means that the second, third, and fourth quadrants are projected onto the first quadrant.

Mathematical Formula 6 has an order of +, +, -, -. This order is changed according to the order(n) and repetition(m). In this way, the information of the input image in all the four quadrants is concentrated in the first quadrant. Thus, it is possible to rapidly obtain a Zernike moment by multiplying the information in the first quadrant by the Zernike moment basis function.

As the present invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, it should also be understood that the above-described embodiments are not limited by any of the details of the foregoing description, unless otherwise specified, but rather should be construed broadly within its spirit and scope as defined in the appended claims, and therefore all changes and modifications that fall within the meets and bounds of the claims, or equivalences of such meets and bounds are therefore intended to be embraced by the appended claims.

INDUSTRIAL APPLICABILITY

As described above in detail, it is possible to extract a Zernike/Pseudo-Zernike moment in real time according to the embodiments of the present invention.

In addition, in the present invention, system loads can be reduced more substantially by decreasing memory utilization during moment extraction to 1/4, as compared to the conventional art.